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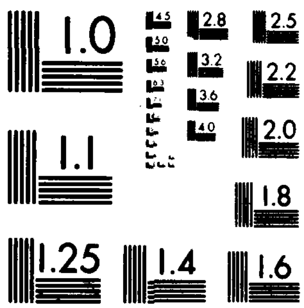

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Prepared by
US Army Engineer Studies Center
Corps of Engineers

June 1981

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This monograph assesses the value of protective construction and attempts to clarify the question of its cost-effectiveness as it affects the engineer battalion. By reviewing the work of others, it shows that protective construction is effective, both historically and analytically. It also provides an estimate of effort required for minimum level of protective construction, draws conclusions relative to its cost benefit, shows that it has a high payoff, and hopefully provides for better decisions as to how much engineer effort can and should be diverted to survivability.

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CONTENTS

ABSTRACT

This monograph is another of a series prepared under the umbrella study, Engineer Assessment Europe (EAE). Since the information contained in this monograph was not used directly in EAE, it was not staffed with either the Study Advisory Group or HQ USAREUR prior to publication. However, the monograph does provide some insights into the value of protective construction. It also sheds some light on the cost of protective construction in terms of engineer battalion requirements. By reviewing the work of others, it shows that protective construction is effective, both historically and analytically. It also provides an estimate of effort required for the minimum level of protective construction and draws conclusions relative to its cost benefit. In conclusion, it is shown that protective construction has a high payoff, and that hopefully better decisions can be made as to how much engineer effort can and should be diverted to survivability.

LIST OF ABBREVIATIONS

ADA............air defense artillery
AMSAA..........United States Army Materiel Systems Analysis Agency
AMSWAG.........AMSAA War Game Simulation

CACDA..........Combined Arms Combat Development Agency
CB/CM..........counter-battery/counter-mortar
CP.............command post
C/V............Chaparral/Vulcan
CWAR...........continuous wave acquisition radar
CY.............cubic yard

E-FOSS.........Engineer Family of Systems Study

FA.............field artillery
FAAR...........forward area alerting radar
FEBA...........forward edge of the battle area
FIST...........fire support team

HERO...........Historical Evaluation and Research Organization
HIPIR..........high-powered illuminator radar

in.............inch

MBA............main battle area
mm.............millimeter
MTI............moving target indicator

NATO...........North Atlantic Treaty Organization

OPLAN..........operations plan

PAR............perimeter acquisition radar

ROR............range only radar

SP.............self-propelled

TA.............target acquisition
TOE............table of organization and equipment
TOW............tube launched, optically tracked, wire-guided missile
TRADOC.........United States Army Training and Doctrine Command
TRASANA........TRADOC Systems Analysis Activity

WP.............Warsaw Pact

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[s]tems Analysis Agency

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dar

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earch Organization
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[ta]cked, wire-guided missile
and Doctrine Command
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SURVIVA[B]ILITY--THE EF[

I. INTRO[

1. Purpose. Intuitively, protecti[
substantial impact on survivability on t[
ition is not a sufficient basis for ma[
Military planners must have more subst[
vided, the real question is not just w[
struction, but is protective constructio[
to answer that question. Its purpose is[
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also presents broad, general results [
(engineer and nonengineer) some indicati[
tective construction. Hopefully, this [
the small unit (company and battalion)[
which will further the effort toward m[
survivability requirements.

2. Scope. This paper is limited [
which engineers can contribute throug[
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below ground level or behind berms.) I[
ically the effect of protective const[
effort required to provide a minimum [
representative Army units, and draws c[
of protective construction. There is[

disprove the value of protective construction or to develop new or original insights. The paper simply presents the intuitive or analytic results of other people's work for the reader's own interpretation.

3. Background. NATO forces in Europe can expect to fight outnumbered and outgunned. Defending forces will face several times their number of armored vehicles, direct- and indirect-fire weapons, and tactical aircraft. What is needed is something to prevent the large WP forces from becoming overwhelming forces. Protective construction can be that something. An outnumbered force cannot afford equal losses; but by limiting exposure to the attacker's weapons, the defender can survive to destroy the attacker. While protected positions cannot eliminate the defender's vulnerability, they can reduce it to the point where disproportionate and crippling losses can be inflicted on the attacker.

4. Statement of the Problem.

a. Historically, we know that protective construction has had a positive impact on the battlefield. We also know that by encouraging the soldier to stand and fight, protective construction contributes much more than its physical effects. This point was made by BG SLA Marshall in an article entitled "Man Against Armor."1/

> In sum, the requisite condition is this--that in the mind of the infantryman using the weapon on the ground it must seem reasonably apparent that at hand there is effective cover, that he has an advantaged position over the enemy armor, whether that position puts him on the flank of his target or prevents the armor from directly sighting on him. Then he will likely fight his weapon whether it be a recoilless rifle, bazooka, wire-guided missile, or even a tank-killing grenade.

1/ BG SLA Marshall, "Man Against Armor," Armor. January-February 1980 (UNCLASSIFIED).

> But expecting the infantryman to stand firm and die hard simply because he has a superior weapon in his hand that can kill tanks at heretofore undreamed ranges is no good. Men are not made that way and training will not make them over. The knowledge that the hardware he carries has an unprecedented potential for working massive destruction over a great distance will not steel his arm nor lift his spirit one degree if he is nakedly in the open. The reality that boggles his mind is that the oncoming enemy tanks out there can snuff out his life in the next several seconds. At whatever range fire is opened and however weaponed, the infantryman cannot bear the brunt of a head-on assault by armor with any prospect of success.

b. We also know that experienced military planners recognize the advantages of protective construction. This was evidenced by the results of a workshop conducted at CACDA as part of the TRADOC E-FOSS.[2/] The purpose of this workshop was to identify, quantify, and prioritize requirements for combat engineer support during a WP/NATO conflict in Europe. Players from various branches of the Army were asked to replay some combat scenarios and identify, quantify, and prioritize the engineer tasks required for the support of their units. Requests for engineer support were grouped in four categories: mobility, countermobility, survivability, and general engineering. Survivability requests were more frequent than all others combined--87 percent; construction of primary fighting positions was the task most frequently requested--22 percent of all tasks.

c. Additional evidence of the importance of survivability was presented in an 8-9 April 1981 systems program review at the Engineer School. This conference was held to review the most recent information and philosophy

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2/ Department of the Army, United States Army Training and Doctrine Command, United States Army Engineer School, Combat Development Engineer Family of Systems Study (E-FOSS) (U). Fort Belvoir, Virginia, February 1979 (SECRET). (Abbreviated to E-FOSS in subsequent references.)

on mobility-countermobility-survivability systems. During the review, it was stated that survivability is "critical at the initiation of the threat attack....This means we must dig in early."[3/]

d. Although the desirability of protective construction has long been recognized by military planners, it has not been included consistently in OPLANs. One factor contributing to its neglect is the feeling that the degree of engineer effort required will not be available--that engineers will be too busy with tasks considered by commanders to have higher priority. Another factor is that, while military planners might concede intuitively that protective construction is valuable, they do not have quantitative proof of its value. What is needed is more proof of just how much better off the defender is with prepared positions than without them. What is also needed is an estimate of how much engineer effort is required to provide that protection. With the aid of such information, a decision can better be made as to how much engineer effort can and should be diverted to the survivability task.

5. Definitions.

a. Survivability--protective position development. Development of earth berms, dug-in positions, overhead protection, and countersurveillance measures to reduce the effectiveness of enemy weapon systems.[4/]

b. Protective construction--construction which offers some degree of artificial concealment or protection from direct small arms, fire, air bursts, etc.

3/ Department of the Army, United States Army Training and Doctrine Command, United States Army Engineer School, Mobility-Countermobility-Survivability Systems Program Review (M-CM-S-SRR 81) (U). ATZA-CD-SPR, Memorandum for Record. Fort Belvoir, Virginia, 15 May 1981 (SECRET-NOFORN).

4/ Department of the Army, Headquarters, FM 5-100, Engineer Combat Operations. Washington, D. C., 30 March 1979 (UNCLASSIFIED).

c. Hasty defense--a quickly organized defense normally necessary when in contact with the enemy or when contact is imminent and there is limited time available for organization.

d. Prepared defense--a well-organized defense by a defender who has had enough time to organize the defensive position but not as much time as is available in preparing a fortified position.

e. Fortified defense--a comprehensive coordinated defense system prepared by a defender with sufficient time to complete planned entrenchments, field fortifications, and obstacles in such a manner that permits the most effective possible employment of defensive firepower.[5]

5/ Historical Evaluation and Research Organization, The Value of Field Fortifications in Modern Warfare (U). Draft Appendix C. Dun Loring, Virginia, 1979 (UNCLASSIFIED). (Abbreviated to HERO report in subsequent references.)

II. EFFECT OF PROTECTIVE CONSTRUCTION

6. General. HERO, TRASANA, and AMSAA have prepared some of the more recent studies on survivability or the value of protective construction. This section uses these studies as a source of information for highlighting the potential value of protective construction.

7. Historical Cases. The history of the independence of the United States begins with lessons in the value of field fortifications. At Lexington, militia standing in the open suffered eight killed, while wounding one British soldier and one horse, and dispersed without making a serious stand. By contrast, at Bunker Hill an entrenched force held its position against repeated assaults until it ran out of ammunition. The Bunker Hill defenders inflicted 1,054 casualties and received only 500 and most of the American casualties occurred after the ammunition gave out. More recent examples of the utility of field fortifications are discussed in the HERO report and are summarized below.

a. In World War II, the European theater of operations was replete with uses of protective positions. Examples cited in the HERO study include:

(1) The Mannerheim Line. This line was a fortified Finnish defense line which extended across the Karelian Isthmus north of Leningrad. It was important as a defensive position because it was the only area where the Russians could concentrate large numbers of troops for offensive operations against the Finns. The Soviets attacked the line twice, but had the line not been prepared, the first attack would have been successful and Finland would have surrendered several months earlier. In this case the Finnish defensive line did not keep them from surrendering; however, the Soviets suffered tremendous casualties in their offensive campaign.

(2) The Maginot Line. This continuous defensive line, located in the eastern part of France, was designed to protect France from invasion by Germany. It has often been said that this line failed to protect France from the Germans and is cited as an example when arguing against fortifications. However, the major attack by the Germans was made in an area which was never fortified because the French General Staff considered it "impenetrable." Hence, history shows that the Maginot Line itself was never seriously tested.

(3) West Wall. The West Wall (or Siegfried Line) was built in Germany's western frontier in the late 1930's. It was dismantled because it was considered obsolete, but it still remained a formidable obstacle to Allied armies. It has been said that if the West Wall had not existed, World War II probably would have ended nearly a year earlier.

(4) Kursk. The Soviets built one of the most elaborate systems of field fortifications around Kursk. It included nearly 6,000 kilometers of trenches, strongpoints, 1 million mines, antitank ditches, and wire and other obstacles. The Germans could not break through and were forced by counter-attacks to withdraw.

b. In the Korean War, the South Korean forces used hasty field fortifications and obstacles to great effect in slowing the North Korean advance. In 1951, when the front stabilized approximately along the 38th parallel, both sides fortified their positions. These fortifications led to the protracted stalemate that characterized the last phase of the war.

c. In Vietnam, fortifications had mixed results. A false sense of security led to heavy French losses along the Chinese border and at Dien Bien Phu. Hamlets fortified by the Americans served as centers of resistance and refuge in the countryside. The strongpoint at Khesanh, which was built to

command a major North Vietnamese supply route, withstood a 3-month seige and repelled every North Vietnamese attack.

d. In the October 1973 war, the Bar Lev line fortifications served the purposes for which they were designed. They delayed and impeded Egyptian attacks, thereby providing time for the Israelis to mount a counterattack with mobile reserves. On the Golan front, fortifications were instrumental in preventing the Syrians from penetrating into Galilee.

8. Historical Cases Versus War Game Results. The study of historical examples leads to the conclusion that protective construction is valuable, but does not answer the question, "How valuable?" The answer to that question requires comparison of the results of the same battle fought with and without fortifications. Attempts have been made to fight such comparative battles by mathematical simulation. HERO developed a mathematical model which they apply to the historical data of a battle fought either with or without fortifications and re-fight the battle in the opposite posture. Thus, they can analyze a battle where the defender used field fortifications and compare the results to what would have occurred if only a hasty defense had been used. Similarly, they can analyze a battle where a hasty defense was used and develop what would have been the outcome if the defender had fortified his position.[6/]

a. Fortified prepared defense.

(1) Historical cases. HERO selected eight historical battles "in which the defender made extensive use of fortifications which apparently

6/ The model has been verified by comparing its developed results to historical battle outcomes. Results correspond closely, lending confidence to the opposite-posture comparisons.

affected the outcome"[7/] of a battle. The following paragraphs briefly describe these eight examples.

(a) Kursk-Prokhorovka. The Kursk-Prokhorovka battle, 4-8 July 1943, was fought between the Soviet XXIII Guards Rifle Corps (defender) and the German II SS Panzer Corps (attacker) on the southern flank of the heavily fortified Kursk bulge in the Eastern Front.

(b) Kursk-Oboyan. The Kursk-Oboyan battle, 5-13 July 1943, was fought between two defending Soviet army groups--Central Army Group and Voronezh Army Group--and the attacking German XLVIII Panzer Corps. This battle was fought west of Kursk between Orel and Belgorod in the central region of the Eastern Front.

(c) Nikopol. The Nikopol Bridgehead is located on the Dnieper River in the Ukraine. Between 31 January and 5 February 1944, the German 335th Infantry Division defended their fortified position from the attacking Soviet rifle corps.

(d) Bowling Alley. The Bowling Alley Offensive, 16-19 February 1944 was fought north of the Anzio beachhead at a group of buildings called the Factory. The German Fourteenth Army assembled thousands of men and hundreds of tanks to attack the US 45th Infantry Division which had a force of less than one-half that of the Germans.

(e) West Wall. After the breakout of Allied forces in Normandy, the West Wall was the only remaining "...formidable obstacle between the Allies and the Rhine River."[8/] This battle was fought along a line running from Maastricht to Luxembourg between the US First Army's VII and XIX Corps and the German LXXXI Corps.

7/ HERO report, p. 1.
8/ HERO report, p. 31.

(f) Seelow. The Germans considered the Seelow Heights sector east of Berlin to be the key approach to that city. The 16-17 April 1945 battle fought there was between the defending German 303d Infantry Regiment and the opposing Soviet 57th Guards Rifle Division.

(g) Suez. On the east bank of the Suez Canal is the Bar Lev Line which is made up of a series of fortified observation posts. On 6 October 1973, the Egyptians crossed the canal and attacked the Israelis.

(h) Ahmadiyeh. During 6-7 October 1973, the Syrian 7th Infantry Division launched an attack on the Israeli 7th Armored Brigade. This attack took place in the Ahmadiyeh sector of the Golan plateau where the Israelis had been building fortifications along the eastern edge of the plateau.

(2) Comparative results. This paragraph shows the results of HERO's comparative analysis. It shows personnel and tank losses by both the attacker and defender in both the historical fortified defense situation and a hypothetical hasty defense situation.

(a) Effect on attacker. Figure 1 shows the effect of prepared positions on the attacker.

1. Personnel casualties. Figure 1 shows that across all battles, the attackers suffered a 16-percent increase in daily personnel casualties. However, in some individual cases, the attacker's casualties actually decreased. At Nikopol, the casualties were relatively low and did not differ much for either side because of cold weather. At West Wall, the personnel casualties appear to be higher when attacking a hasty defense rather than a fortified defense. However, the casualties are actually lower if the prisoner of war casualties (79 percent of total) are subtracted.

Se[illegible]	1.71	1.17	1.46	51.56	22.58	2.28
[illegible] (N)	0.72	0.81	0.89	17.65	29.41	0.60
Ahmadi[illegible]h	1.67	1.03	1.62	[illegible]9.[illegible]	27.91	1.76
[illegible]erage	1.28	1.10	1.16	20.20	16.59	1.22

a/ Percent casualties losses for actual historical cases in which defending force used fortified positions.
b/ Percent casualties/losses for replicate (hypothetical) battles in which defending force used [illegible]st positions.
c/ [illegible]io of casualties/losses for a fortified defense versus a hasty defense.

Figure 1

2. Tank losses. attacking force. Once again, there are losses actually decreased (e.g., West Wal attacker had a 22-percent increase in tar

(b) Effect on defende to Figure 1 except that it highlights th defender instead of the attacker.

1. Personnel cas cases except the Suez, the defender's fortified defense position rather than a to the short length of conflict, the ca had unmeasurable differences. Across a percent fewer casualties when defending than a hasty defensive position.

2. Tank losses. Prokhorovka and Bowling Alley), the defer fortified rather than a hasty defense defender lost 44 percent fewer tanks.

b. Hasty defense.

(1) Historical cases. HER which the defender had little or nothi positions."[9]

(a) Aprilia. The 25- fought near the Factory complex where

9/ HERO report, p. 1.

EFFECT OF PREPARED POSITIONS ON DEFENDER
(Fortified Versus Hasty Defense)

Battle	Personnel Casualties (% Per Day)			Tank Losses (% Per Day)		
	Fortified Position[a/]	Hasty Position[b/]	Fortified/Hasty[c/]	Fortified Position[a/]	Hasty Position[b/]	Fortified/Hasty[c/]
Kursk-Prokhorovka	2.74	3.89	0.70	15.51	0.00	--
Kursk-Oboyan	1.63	2.77	0.59	8.63	44.63	0.19
Nikopol	0.42	0.43	0.98	--	--	--
Bowling Alley	2.48	2.82	0.88	24.38	23.19	1.05
West Wall	1.41	1.71	0.83	10.40	10.53	0.99
Seelow	1.36	3.49	0.39	11.11	20.00	0.56
Suez (N)	2.94	2.94	1.00	25.37	43.28	0.59
Ahmadiyeh	1.70	2.81	0.61	15.07	27.94	0.54
Average	2.44	3.25	0.75	22.27	39.85	0.56

a/ Percent casualties/losses for actual historical cases in which defending force used fortified positions.

b/ Percent casualties/losses for replicate (hypothetical) battles in which defending force used hasty positions.

c/ Ratio of casualties/losses for a fortified defense versus a hasty defense.

Figure 2

3 weeks later. Aprilia was defended by elements of the German 3d Panzer Grenadier Division and attacked by the British 1st Infantry Division.

(b) Terracina. During 22-23 May 1944, the battle at Terracina was fought on the right flank of the Hitler line which was one of three partially completed fortified lines constructed in the Italian peninsula south of Rome. The US 85th Infantry Division attacked the fresh 29th Panzer Grenadier Division and the remains of the 15th Panzer Grenadier and 94th Infantry Division.

(c) Valmontone. The battle at Valmontone, 1-2 June 1944, was fought between the American 3d Division and the German Hermann Goering Division. After several days of preliminary fighting, the 3d Division was finally able to accomplish its mission and go on the next day to capture Valmontone.

(d) Sauer River. The Sauer River Defense was a 2-day battle launched by the German 212th Volks Grenadier Division on the US 4th Infantry Division. The Americans had not prepared adequately for the attack and it took help from the US Third Army to stop the Germans.

(e) Jebel Geneifa. During the 1973 Arab-Israeli War, General Adan's Division mounted a 2-day campaign against the Egyptian Third Army in order to cut its lines of communication. The battle began on 19 October 1973. By the time of the ceasefire at 1800 on 22 October 1973, the Israelis had successfully isolated the Egyptian Third Army.

(f) Tel Fars. On 8 October 1973, the Israeli Peled Division counterattacked a 2-day advance of the Syrian 5th Infantry Division and began to push the Syrians back. By 10 October, the Israelis had pushed the Syrians back to the original ceasefire line (the "Purple Line").

:s of the German 3d Panzer Gren-
Infantry Division.

2-23 May 1944, the battle at
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15th Panzer Grenadier and 94th

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the Syrian 5th Infantry Division
October, the Israelis had pushed
fire line (the "Purple Line").

(2) Comparative result
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force was in a hasty defense. HE
defender's force in a fortified def
discuss the results of this HERO a
results for comparative purposes.

(a) Effect on at
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1. Personnel
Aprilia and Terracina, the attacker
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2. Tank los
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when attacking a fortified position
losses increased 58 percent.

(b) Effect on def
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1. Personne
the defender suffered [illegible] percent fe
position than when defending a hasty

10/ HERO report, p. [illegible]2.

EFFECT OF PREPARED POSITIONS ON ATTACKER
(Hasty Versus Fortified Defense)

Battle	Personnel Casualties (% Per Day)			Tank Losses (% Per Day)		
	Hasty Position[a]	Fortified Position[b]	Fortified/Hasty[c]	Hasty Position[a]	Fortified Position[b]	Fortified/Hasty[c]
Aprilia	0.62	0.60	0.97	3.72	4.58	1.23
Terracina	0.56	0.48	0.86	6.91	3.57	0.52
Valmontone	1.05	1.84	1.75	9.56	24.80	2.59
Sauer River	1.12	1.94	1.73	29.00	42.86	1.48
Jebel Geneifa	0.96	0.94	2.04	2.52	5.29	2.08
Tel Fars	4.53	0.97	1.83	3.21	5.62	1.75
Average	0.90	1.39	1.54	9.30	14.74	1.58

a/ Percent casualties/losses for actual historical cases in which defending force used hasty defensive positions.
b/ Percent casualties/losses for replicate (hypothetical) battles in which defending force used fortified positions.
c/ Ratio of casualties/losses for a fortified defense versus a hasty defense.

Figure 3

EFFECT OF PREPARED POSITIONS ON DEFENDER
(Hasty Versus Fortified Defense)

Battle	Personnel Casualties (% Per Day)			Tank Losses (% Per Day)		
	Hasty Position a/	Fortified Position b/	Fortified/Hasty c/	Hasty Position a/	Fortified Position b/	Fortified/Hasty c/
Aprilia	0.76	1.73	2.28	3.33	7.95	2.39
Terracina	1.15	1.12	0.97	6.00	6.00	1.00
Valmontone	2.04	1.18	0.58	13.33	10.00	0.75
Sauer River	0.63	0.49	0.78	4.37	2.50	0.59
Jebel Geneifa	1.38	2.82	2.04	7.42	15.20	2.05
Tel Fars	1.43	1.46	1.02	8.30	8.30	1.00
Average	1.64	1.43	0.87	10.00	11.76	1.17

a/ Percent casualties/losses for actual historical cases in which defending force used hasty defensive positions.
b/ Percent casualties/losses for replicate (hypothetical) battles in which defending force used fortified positions.
c/ Ratio of casualties/losses for a fortified defense versus a hasty defense.

Figure 4

2. Tank losses. Intuition might suggest that the defender would suffer fewer tank losses when occupying a fortified defense rather than a hasty defense. However, Figure 4 suggests otherwise. Although there are some exceptions (e.g., Valmontone, Sauer River, Tel Fars), the defender generally suffers more tank losses. Across all battles, the defender suffered 17 percent more tank losses when occupying a fortified position rather than a hasty position. This apparent anomaly occurred because the battles lasted longer and the size of the attacking force was increased in strength due to reinforcements.

(c) Loss exchange ratios.

1. In Figures 1 through 4, personnel casualties and tank losses are examined separately for both the attacking and defending forces. When examined separately, the increases and decreases appear to be substantial. However, when examined together, they are even more impressive.

2. Figure 5 shows the effect of prepared positions on personnel casualty and tank loss exchange ratios. In this figure, increased attacker and decreased defender personnel casualties and tank losses are examined simultaneously. As indicated, the personnel casualty exchange ratios vary from 1.54 to 1.77 while the tank loss exchange ratios vary from 1.34 to 2.18. Thus, in terms of personnel casualties, the simultaneous effect of prepared positions on both the attacker and defender is to improve the defender's survivability by from 54 to 77 percent. In terms of tank losses, prepared positions increase the defender's survivability by from 34 to 118 percent.

c. Summary. An examination of Figures 1 through 5 leads to some general conclusions about battles fought with and without prepared positions.

EFFECT OF PREPARED POSITIONS ON EXCHANGE RATIO

Battles	Personnel Casualties		Tank Losses	
	Fortified Position	Hasty Position	Fortified Position	Hasty Position
Battle Averages (7 Battles)[a]				
Attacker	1.28	1.10	20.20	16.59
Defender	2.44	3.25	22.27	39.85
A/D[c]	0.52	0.34	0.91	0.42
F/H[d]	1.54		2.18	
Battle Averages (6 Battles)[b]				
Attacker	1.39	0.90	14.74	9.30
Defender	1.43	1.64	11.76	10.00
A/D[c]	0.97	0.55	1.25	0.93
F/H[d]	1.77		1.34	

a/ Average of seven battles examined in Figures 1 and 2.
b/ Average of six battles examined in Figures 3 and 4.
c/ Attacker's casualties divided by defender's casualties (same type position)
d/ Exchange ratio factor. Computed by dividing the A/D for a fortified position by the A/D for a hasty position.

Figure 5

Prepared positions cause the attacker to suffer more personnel casualties and tank losses. They also cause the defender to suffer fewer casualties. Based on the few battles HERO examined (with and without prepared positions), it appears that the attacker will suffer somewhere between 16 to 54 percent more personnel casualties and between 22 to 58 percent more tank losses. The defender will not only inflict more personnel casualties and tank losses on the enemy, but will also suffer fewer casualties. In the same battles, the defender's personnel losses were reduced as much as 25 percent and tank losses were reduced by as much as 44 percent. In terms of personnel casualty and tank loss exchange ratios, the value of prepared positions is even more impressive. In terms of personnel casualties, they increase the defender's survivability by as much as 77 percent; in terms of tank losses, they increase survivability by as much as 118 percent.

9. Other War Game Results.

a. General. In the discussion above, HERO compared historical results with analytically derived results to determine the effects of protective construction. Several other analytic groups have used purely analytic methods (war gaming) to similarly test the effects of protective construction. In support of E-FOSS, AMSAA conducted extensive analysis to determine the effect of protective construction using its AMSWAG model.[11] Also in support of E-FOSS, the TRASANA conducted similar analyses using its CARMONETTE

11/ Department of the Army, United States Army Materiel Systems Analysis Activity, Effects of Specific Engineer Tasks Supporting a Small Unit Action (U). Aberdeen Proving Ground, Maryland, 1977 (CONFIDENTIAL).

model.[12] The fo'lowing paragraphs summarize the effects of protective construction as developed in these two analyses.

b. TRASANA (CARMONETTE model).

(1) Scenario. The TRASANA CARMONETTE model was used to war game a situation in an area of approximately 6 square kilometers between the Fulda and Haune Rivers just north of Hunfeld. The defending US forces were deployed in and around the town of Burghaun and on the high ground south and west of the Haune River. A Soviet division is assumed to attack this force from the Northeast. This scenario was based on the use of 1985 weapon systems and involved an initial tank attack, direct and indirect fire by both sides, breaching of barriers, preparation of positions by both sides, smoke, and camouflage. Vehicles in protected positions were considered to be in hull defilade. Unprotected vehicles were credited with the degree of natural cover at their locations.

(2) Comparative results. TRASANA found that of all the alternatives considered (i.e., minefields, camouflage, smoke), preparation of positions had the most favorable effect on the loss exchange ratio. Figure 6 shows the loss exchange ratios for prepared and unprepared sites and the exchange ratio factor. As indicated, prepared positions for the defending force allowed the US forces to increase the vehicle loss exchange ratio by 140 percent.

c. AMSAA (AMSWAG Model). AMSAA also ran a model in support of the E-FOSS study. In this analysis, AMSAA evaluated an ambush of a Soviet

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12/ Department of the Army, United States Army Training and Doctrine Command, United States Army TRADOC Systems Analysis Activity, Effects of Barriers in a Combat Environment (U). White Sands Missile Range, New Mexico, 1978 (CONFIDENTIAL).

battalion by a US company. The ambush was gamed in an area roughly 6 kilometers west of Fulda using 1979 weapon systems. The defending team was deployed in fixed positions and the attacking team advanced on predetermined routes. Figure 7 shows the effect of the defender developing a prepared defensive position. As the level of preparations increases, the Soviet casualty rates and vehicle loss rates also increase. Figure 7 shows that the Soviet to US casualty ratios can increase by as much as 60 percent and that the vehicle loss ratio can increase as much as 65 percent.

EFFECT OF PREPARED POSITIONS ON VEHICLE LOSSES[a]

Site Preparation	Loss Ratio[b]	Exchange Ratio[c]
Unprepared position	1.16	2.4
Prepared position	2.78	--

a/ Average of 20 game replications.
b/ Ratio of Soviet vehicle losses to US vehicle losses.
c/ Prepared site loss exchange ratio divided by unprepared site loss exhange ratio.

Figure 6

EFFECTIVENESS OF DEFENDER POSITION PREPARATION

Degree of Preparation	Personnel Casualties		Vehicle Losses	
	Loss Ratio[a]	Exchange Ratio[b]	Loss Ratio[a]	Exchange Ratio[b]
Hasty	2.19	--	2.24	--
1/3 Prepared, 2/3 Hasty	2.37	1.08	2.46	1.10
2/3 Prepared, 1/3 Hasty	2.92	1.33	3.09	1.38
Fully Prepared	3.52	1.61	3.73	1.67

a/ Ratio of Soviet to US casualties or losses.
b/ Effect of position preparation on loss ratio.

Figure 7

d. Summary. As in the historical case presented in paragraph 8, the analyses presented above show that there can be substantial benefits from the use of protective construction. Whereas the historical cases compared the favorable effect of a fortified position with a hasty prepared position, the above results compare the effect of a hasty prepared position with no preparations at all. In these cases, it appears that a defender using a prepared position can increase the attacker-to-defender vehicle loss exchange ratio by from 65 percent (AMSWAG results) to 140 percent (CARMONETTE results). The AMSWAG results also indicate that the attacker-to-defender personnel loss ratios can be increased by nearly 60 percent.

III. EFFORT FOR PROTECTIVE CONSTRUCTION

10. General. The preceding discussion shows that protective construction can significantly improve the chances of a successful defense. However, it is neither possible nor practical for engineers to construct protected positions for everyone and everything on the battlefield. Therefore, military planners must decide what to protect, how much of it to protect, and the degree to which it is to be protected. The following paragraphs address these points.

11. What to Protect.[13/]

a. The decision on what to protect, while subjective, should be based on the following criteria:

(1) Exposure to fire--direct, indirect, tactical air.

(2) Vulnerability to discovery and location--electronic emissions (communications and radar), firing signature, trackable projectiles, requirement to operate in the open.

(3) Mobility—capability to move to avoid detection or to displace before counterfire arrives.

(4) Armor protection--a factor in vulnerability to small arms and indirect artillery and mortar fire.

(5) Distance from the FEBA--affects likelihood of acquisition as a target, vulnerability to artillery and tactical air, chance of direct contact with enemy.

13/ Department of the Army, United States Army Corps of Engineers, Office of the Chief of Engineers, US Army Engineer Studies Center, Engineer Assessment Europe (U). Volume IV, Appendix D-9. Washington, D. C., February 1981 (SECRET--RELEASABLE TO NATO MEMBER NATIONS). (Abbreviated to EAE Appendix D-9 in subsequent references.)

natural cover.

importance of a unique equipment item loss
nt worthless. An example is air defense . ~e

eria to units operating in the MBA leads to
s, field artillery, and ADA are the organiza-
lity assistance. Figure 8 shows, for each
ems of equipment that might need protective

The amount of protective construction engi-
least two factors. First, some Army units,
the battlefield, are more likely to find
the amount of protective construction to be
ill depend on the number of positions desired

rotection.[17] Not all units (and equipment)
:tion. Map analysis indicates that, through-
0 percent of direct-fire vehicles could be
ns with natural hull-down cover. Thus, on
t-fire weapons might require protective con-
pons as a base, other items of equipment are
lative opportunity of finding natural protec-

ITEMS/SYSTE

Function
Air Defense Artillery
Armor and Armored Cavalry
Field Artillery
Infantry and Mechanized Infantry

a/ Includes FAAR for ... Hawk.

(1) Radar, having ... for 360-degree surveillance, is ... tion.

(2) ADA fire and c... fire in all directions, may be

direct-fire vehicles to use natural cover. ADA control systems, which must be located nearby and are unique equipment items, are also assumed to have half the natural cover opportunity of direct-fire vehicles.

NATURAL COVER AVAILABILITY

Item/System	Factors Relative to Direct-fire Vehicles	Percent Finding Natural Cover
Radar[a/]	0	0
ADA Fire and Control Systems[b/]	.5	15
Direct-fire Weapons[c/]	1.0	30
Field Artillery Weapons and Ammunition Carriers	1.5	45
Mortars	2.0	60
Command Posts	2.0	60

a/ Includes FAAR (Vulcan/Chaparral); PAR, CWAR, ROR (Hawk); FA target acquisition radar vans.
b/ Includes Hawk, Vulcan, and Chaparral.
c/ Includes tanks, TOW carriers, and personnel carriers.

Figure 9

(3) Field artillery weapons and ammunition carriers normally are situated a distance from the FEBA and behind a mask. They are, therefore, assumed to have 1.5 times the opportunity of finding natural protection as direct-fire weapon systems.

(4) Mortars, which occupy smaller areas than artillery and are more easily displaced, have twice the opportunity of direct-fire weapon systems.

(5) Command posts, with considerable freedom of location, are also estimated to have twice the opportunity.

ɔn, it is desirable to have more than
Alternate positions are required to
Also, supplementary positions may be
:ed from primary and alternate firing

ression of increments for survivabil-
tions. The increment to be selected
urces. The figure considers two lev-
the most exposed and easily acquired
iers, Chaparral, and Vulcan. Level B
to target items--Hawk control and fire
mand posts. The survivability incre-
the minimum of a primary position only
in Level B (Increment 1), and up to
Level B items (Increment 6). The
rnate or supplementary as dictated by

ing paragraphs show how much engineer
l emplacements, small unit positions,

rements. Figure 11 shows the engineer
: construction for certain weapon sys-
ample of tasks and engineer equipment
ent requirements are based on the use

of currently available equipmen
items of equipment organic to al
equipment-hours required to dig
these figures are only for on-si
to and from the site.

SURVI

Level	Item/System
A	Radar Direct-fire Weapc ADA Fire and Control Systems
B	ADA Fire and Control Systems Field Artillery Weapons and Ammu Carriers Mortars Command Posts

a/ Increments 1 and 2 are for alternate positions, and I tions. Numbers listed below i developed for each item/system.
b/ Includes tanks, TOW ca
c/ Includes only the Vulc
d/ Includes Hawk only.

b. Small unit suppo
shows the results of applying
of equipment organic to repr

ENGINEER EQUIPMENT REQUIREMENTS FOR PROTECTIVE CONSTRUCTION

Task	Dozer D-5	Dozer D-7	Loader 2.5 CY	Truck and Trailer 2.5 Ton	Truck and Trailer 5 Ton	Truck and Trailer 10 Ton	Total
	Equipment-hours						
Dig in CP or exec post for towed arty (inf div)	.45	1.58	1.80	.45	.45	1.80	6.53
Dig in infantry TOW carrier	--	.45	--	--	--	.45	.90
Dig in armored car TOW carrier	--	.45	--	--	--	.45	.90
Construct berm for FAAR	--	.90	.90	--	--	.90	2.70
Dig in infantry personnel carrier	--	.45	--	--	--	.45	.90
Dig in armored personnel carrier	--	.45	--	--	--	.45	.90
Dig in armored car personnel carrier	--	.45	--	--	--	.45	.90
Dig in armored tank	--	.45	--	--	--	.45	.90
Dig in armored car tank	--	.45	--	--	--	.45	.90
Dig in artillery personnel carrier (FIST)	--	.45	--	--	--	.45	.90
Construct berm for CB/CM radar (FA)	-	.45	--	--	--	.45	.90
Dig in Vulcan SP	-	.45	--	--	--	.45	.90
Construct berm for PAR (Hawk)	--	1.58	--	--	--	1.58	3.16
Construct berm for Chaparral	-	.90	-	--	--	.90	1.80
Construct berm for ROR (Hawk)	-	1.58	--	--	--	1.58	3.16
Construct berm for CWAR (Hawk)	-	1.58	--	--	--	1.58	3.16
Cut slot for battery CP (Hawk)	-	1.80	1.80	--	--	1.80	5.40
Construct berm for MTI radar (FA)		--	--	--	--	--	--
Cut slot for platoon CP (Hawk)		.60	.70	--	--	.60	1.90
Construct berm for HIPIR (Hawk)	--	1.58	--	--	--	1.58	3.16
Dig in 8-inch howitzer SP	--	.82	.82	--	--	.82	2.46
Dig in infantry CP carrier	--	.45	--	--	--	.45	.90
Construct berm for Hawk launcher	--	2.10	--	--	--	2.10	4.20
Construct berm for generator (Hawk)	--	1.13	--	--	--	1.13	2.26
Dig in armored CP carrier	--	.45	--	--	--	.45	.90
[illegible]	--	.45	--	--	--	.45	.90
[illegible]	--	.45	--	--	--	.45	.90
Dig in infantry mortar carrier	--	.45	--	--	--	.45	.90
[illegible] mm howitzer SP	--	.82	.82	--	--	.82	2.46
[illegible] armored mortar carrier	--	.45	--	--	--	.45	.90
[illegible] armored [illegible] carrier	--	.45	--	--	--	.45	.90
[illegible]	--	.16	.16	--	--	.16	.48
[illegible]	--	.45	--	--	--	.45	.90
[illegible] towed	.45	--	--	.45	--	--	.90
[illegible] howitzer [illegible] inf div)	--	--	.28	--	--	.28	.56
[illegible] howitzer [illegible] abn div)	.42	--	--	--	.42	--	.84
[illegible] howitzer [illegible] towed (ambl div)	.42	--	-	.42	--	--	.84
[illegible] howitzer [illegible] towed	--	.35	--	--	--	.35	.70
[illegible] for towed arty [illegible]	--	.30	.30	--	--	--	.60
[illegible] for towed arty [illegible]	.45	--	.30	--	.45	--	1.20
[illegible] for towed arty [illegible]	.45	--	.30	.45	--	--	1.20
[illegible] information coordination [illegible] Hawk	--	.60	.70	--	--	.60	1.90

Figure 11

SURVIVABILITY EQUIPMENT-HOURS TO DIG ONE POSITION
FOR MANEUVER AND ARTILLERY UNITS[a]

Function	Unit		Level of Support		
	Size	Type	Level A	Level B	Total
Air Defense	Battalion	C/V (SP)	53.10	.90	54.00
	Battalion	Chaparral (SP) /Vulcan (towed)	53.10	.90	54.00
	Battalion	Vulcan (towed)	44.10	1.80	45.90
	Battalion	Hawk (triad)	23.70	158.72	182.42
Armor	Brigade	Separate	166.50	51.60	218.10
	Squad	Air cavalry (abn div)	7.20	0	7.20
	Squad	Air cavalry (airmobile div)	18.00	1.80	19.80
	Cavalry	Regiment	234.90	23.40	258.30
	Squad	Cavalry	58.50	7.20	65.70
	Troop	Cavalry	18.00	1.80	19.80
	Battalion	Tank	45.90	3.60	49.50
Field Artillery	Battalion	105-mm towed	0	10.70	10.70
	Battalion	155-mm SP (div)	3.60	35.40	39.00
	Battalion	155-mm SP (nondiv)	0	33.00	33.00
	Battalion	155-mm towed	0	12.10	12.10
	Battalion	155-ton/8-in SP	3.60	18.28	21.88
	Battalion	175-mm SP	0	24.18	24.18
	Battalion	8-in SP (div)	0	25.08	25.08
	Battalion	8-in SP (nondiv)	0	24.18	24.18
	Battery	TA	.90	0	.90
Infantry	Battalion	Airborne	18.00	0	18.00
	Battalion	Airmobile	11.70	0	11.70
	Brigade	Separate	53.10	38.60	91.70
	Battalion		11.70	8.70	20.40
	Brigade	Mechanized, separate	128.70	32.00	160.70
	Battalion	Mechanized	53.10	7.20	60.30
	Company	Antiarmor	23.40	0	23.40
	Battalion	Ranger	0	0	0

a/ Assumes natural defilade positions available for: direct-fire artillery = 30%, indirect-fire artillery = 45%, C/V air defense = 15%, radar = 0, mortar = 60%, Hawk = 15%, command vehicles = 60%. Equipment-hours include bulldozer, transporting tractor-trailer, and front loader requirements.

b/ This number is the total equipment-hours required for all systems to dig one position to Increment 2.

Figure 12

noted, the engineer support requirement shown in Figure 12 is to construct only one position for all items or systems assumed to require protection.

c. Division support requirements. Figure 13 shows the engineer requirements to dig in an entire division by survivability increment. The engineer support requirements to dig in a heavy division varies from 5 to 21 engineer battalion-days of effort. The 21 battalion-days of effort are based on providing three positions for all equipment items or systems to be protected (Increment 6). However, due to time and resource constraints, the typical level of support that might be provided will probably fall in the 2 to 3 increment level. Therefore, even though the engineers might continue developing protective positions until Increment 6 is achieved, the planning goal actually should be to provide for the 2-3 increment level of support. To support a heavy division at survivability Increment 2 (a primary position for all vulnerable items/systems) requires approximately 7 battalion-days of engineer effort. To support a heavy division at survivability increment 3 (a primary and alternate position for the most vulnerable items/systems and a primary position for the least vulnerable items/systems) requires approximately 13 battalion-days of engineer effort.

ENGINEER REQUIREMENTS TO DIG IN A DIVISION

Type Division	Survivability Increment[a/]					
	1	2	3	4	5	6
Armor/Mech Division						
Equipment-hours[b/]	692	201	692	201	692	201
Battalion-days[c/]						
(By Increment)	5.5	1.6	5.5	1.6	5.5	1.6
(Cumulative)	5.5	7.1	12.6	14.2	19.7	21.3
Infantry Division						
Equipment-hours[b/]	259	123	259	123	259	123
Battalion-days[c/]						
(By Increment)	2.1	1	2.1	1	2.1	1
(Cumulative)	2.1	3.1	5.2	6.2	8.3	9.3

a/ See Figure 10 for weapon systems and number of positions included in each increment.

b/ Includes only bulldozer, transporting tractor-trailers, and front loaders (47% bulldozers, 47% tractor-trailers, 6% front loaders).

c/ Corps combat engineer battalion (TOE 5-35H) used as basis of capability.

Figure 13

IV. CONCLUSIONS

14. Value of Protective Construction.

a. A prepared defensive position gives the defender a more favorable advantage with respect to the attacker than does a hasty position. The analyses examined in this paper indicate that the use of prepared positions can cause longer and more successful defenses. This is due to reductions in the defender's losses, increases in the attacker's losses, and substantial increases in loss exchange ratios (e.g., ratio of attacker to defender losses).

b. An examination of 13 historical battles indicated that the use of protective construction substantially increased the survivability of the defending force. When evaluated in terms of personnel casualties, protective construction increased the survivability of the defending force by from 54 to 77 percent. When evaluated in terms of tank losses, protective construction increased the survivability of the defending force by from 34 to 118 percent.

c. An examination of several purely analytically derived measures of effectiveness produced similar results. In one war-gamed scenario using 1979 US/WP forces, protective construction increased the defending force survivability by 60 percent. In another war-gamed scenario using 1985 US/WP forces, protective construction increased the defender's survivability by 140 percent.

15. Effort to Provide Protection.

a. Infantry, mechanized infantry, armored, field artillery, and ADA units are the principal Army units most in need of protective construction. The amount of protection required will vary with the terrain occupied and the vulnerability of specific weapon systems or items of equipment. It will also

vary due to the tactics being employed by the supported unit and the preferences or desires of the supported unit commander.

b. There are six levels of protective construction that should be considered for the modern battlefield. The first level should consist of providing selective (primary) positions for the most exposed and easily acquired items or systems (e.g., tanks, radars). The second level should consist of providing selective (primary) positions for all other less exposed or more difficult to target items or systems (e.g., mortars, field artillery pieces). Levels 3 through 6 should consist of providing alternate and supplemental positions on a selective basis for the same items or systems.

c. The effort required to provide protective construction is relatively small. Even with currently authorized equipment (e.g., the medium tracked bulldozer), the on-site construction time is not extensive. A single engineer battalion can dig in an entire infantry division (primary positions only) within 3 days. The same battalion can dig in an armored division within 7 days. Also, that same battalion can simultaneously perform other engineer missions (e.g., obstacle construction) with other organic resources. Thus, under long-warning conditions (i.e., 10 days), there should be ample time for the divisional engineer battalion to dig in a division. However, under short-warning conditions (i.e., 2 days), the divisional engineer battalion will have to be reinforced by other battalions--normally there are two to three nondivisional battalions available.

16. Cost-effectiveness of Protective Construction.

a. This paper does not determine the cost-effectiveness relationships of protective positions. In the examination of both historical and analytic cases to determine effectiveness, there was no way to accurately measure the effort required to provide that protection. In the determination

of engineer effort required to dig in certain tactical units, no attempt was made to measure the effect of those same positions. Thus, no simultaneous cost-effectiveness relationships were developed. Despite this, certain general observations can still be made.

b. In all historical and analytic cases examined in this paper, it can be assumed that all defending forces were provided with at least a primary fighting position. In certain historical cases where the battle extended for some duration, the defending force quite likely also was provided with alternate and supplemental positions. In some of the historical cases, the protective positions were concrete and/or timber-type construction rather than the bulldozed slots or earth-filled berms considered in this paper. However, the number and variety of weapon systems and/or items of equipment protected was probably less than that visualized by this paper. Thus, it might be assumed that the level of engineer effort required to provide primary fighting positions could generate an effect that is nearly equal to the lower levels of effectiveness identified in this paper. It might also be assumed that the level of engineer effort required to provide primary, alternate, and supplemental positions for a sustained battle might generate an effect that exceeds the lower levels of effectiveness identified in this paper.

c. If the relationships assumed above are even reasonably close, protective construction has a high payoff. Given the time (approximately 3 days), an engineer battalion can make an infantry division nearly 50 percent more effective. With slightly more time (approximately 5 days), an engineer battalion can increase the effectiveness of an armored or mechanized infantry division by an equal amount. Stated another way, if properly used and with sufficient time, an engineer battalion can generate the equivalent effect of

more than five infantry, mechanized infantry, or armored battalions. Given even more time (i.e., to prepare more extensive alternate and supplemental positions), the engineer battalion could conceivably double the effectiveness of the supported division. Even more impressive is the fact that the same battalion can simultaneously execute other engineer missions (e.g., obstacle construction) that also contribute to the increased effectiveness of the supported division.

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